ORIGINAL ARTICLE

Body build, body composition and special fitness of female top ju-jitsu contestants

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Abstract

Background & Study Aim: Contemporarily, a phenomenon of the increasing number of women who participate in combat sports has been observed. The aim of this study was to obtain knowledge about body build and body composition and profile of special fitness in women who practice ju-jitsu. This knowledge can be used in monitoring of the status of physical preparation and effects of training in female athletes who represent a variety of weight and age categories.

Material & Methods: The participants of the study were 12 female members of the national ju-jitsu team, aged 19.5 ± 3.23, representing two weight categories: the lighter category up to 55 kg (n=6, 51.72 ± 4.76 kg) and the heavier category (n=6, 65.67 ± 3.88 kg). Body height was measured using an anthropometer. Body mass was measured using a weight scale. The evaluation of body composition was performed under standard conditions according to the bioelectric impedance analysis guidelines. Estimated were the body mass (index BMI) and body composition (FFMI and FMI) parameters. Fitness was assessed by means of a battery of tests used in karate (SPFT) and a judo special fitness test (SJFT). Maximal static strength in the dominant hand (HGS) was measured using a handgrip dynamometer. A Polar 810i heart rate monitor was used. Basic descriptive statistics were calculated. The significance threshold for differences between mean values was $p<0.05$.

Results: A very strong correlation between FMI and FFMI ($r=0.98$, $p<0.001$) was observed. The averages for the lighter group were significantly lower than for the heavier group as per BMI, FFMI, FMI ($p<0.001$) and fat percentage in total mass ($p=0.005$). During fitness evaluation, no statistically significant differences were found between the heavier and lighter weight categories in terms of SPFT, HGS and SJFT ($p>0.05$). The differences between mean values of anthropometric measurements and parameters were not significant for age categories ($p>0.05$). Significant differences were found between the mean values for age categories in the quality of push-ups, segment C of the SJFT, and in total throws. The SJFT index in the older group was better (i.e., lower) than in the younger group.

Conclusions: The body composition of female ju-jitsu athletes is associated with their weight category, but does not affect performance in special fitness tests. The results of tests on rapid kicks, push-ups and special endurance in the SJFT (total throws and index) are dependent on the age factor. Profile analysis enables group and individual diagnosis of fitness preparation. Such diagnosis can be used for the comparison of contestants at the time of measurement, as well as in the process of monitoring changes occurring in a training cycle. The established structure of special fitness among female top ju-jitsu contestants can be used for comparisons with male representatives.

Key words: Ju-jitsu, High competitive level, Female, Age factor, Fat-free mass index, Sport-specific fitness, Technique

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Introduction

Fighting in sport ju-jitsu is a combination of actions typical for karate and judo. According to Ju-jitsu Rules, [1] "the competition is organized on soft mats (i.e. judo mats), conducted by three referees on the mat (called mat referee and side referees) and one at the (score) table. There is only one match (round) of 3 minutes. The fighting system is composed of three stages (such a division is important for scoring, as the fights are very fluent and in principle do not stop even if a point is scored). Contestants may proceed from stage one to stage three and back: (1) punches, strikes and kicks: opponents stand at the centre of the mats; fighting commences when the mat referee says *hajime*. Only semi-contacts are allowed. (2) throws, take downs, locks and strangulations: after establishing contact no punches, strikes or kicks are allowed any more (the rules allow an exception if these moves are enforced simultaneously with the grip); (3) floor techniques, locks and strangulations: when the opponents are on the ground, various ground techniques are allowed. *Ippon* and *waza-ari* are points awarded the in ju-jitsu fighting system. *Ippon* represents 2 points (in stages two and three sometimes even three points in the case of one of the competitors surrendering); *waza-ari* represents 1 point. In principle, the contestant who scored more points after 3 minutes wins. Rules also allow for victory before the end of the regular time (e.g. if a contestant scored *ippon* points in all three stages)." Divisions are used within the fighting system according to gender, weight and age categories; juniors are additionally able to participate in the senior category.

A revision of research papers on the subject shows that the only paper dealing with the temporal structure and effectiveness of tactical-technical elements employed in subsequent fighting stages concerns males [2]. Research to date has also concerned the body build and body composition of karate [3-5] and judo [6-8] trainees, but rarely the body build of ju-jitsu trainees [9, 10]. The authors' findings concern the somatotype and body composition of high-rank male [9, 10] and female [9] sport ju-jitsu contestants. Fitness was evaluated only for male contestants [11]. The method of evaluating contestants' special fitness was suggested to coach course participants, who drew special attention to the need to evaluate high-level ju-jitsu sportspersons [12].

It is undeniably important in sport ju-jitsu to obtain a perfectly profiled model of body build, body composition and special fitness. At the same time, such aim is difficult to achieve, since various compensations may occur for each sportsperson within their individual profile. It was assumed that age, body build and body composition parameters for the group selected for the national team are optimal, and their experience in competitions would aid the acquisition of technical skills used in special training tests. The aim of this study was to obtain knowledge about body build and body composition and profile of special fitness in women who practice ju-jitsu. This knowledge can be used in monitoring of the status of physical preparation and effects of training in female athletes who represent a variety of weight and age categories.

Arm/leg movement speed: a skill-oriented ability underlying actions such as the boxer's jab, for which a limb must be moved from one place to another very rapidly [23].

Agility: the ability to change the position of the body in space rapidly and accurately without loss of balance. Agility is important in sports in which obstacles or the opponent have to be avoided. Agility depends on muscular power, reaction time, co-ordination, and dynamic flexibility [23].

Dynamic flexibility: the ability to move parts of body rapidly, or to make rapid and repeated movements. Dynamic flexibility is greatly affected by the ability of muscles to recover quickly and the forces which oppose or resist the movements [23].

Short term endurance: an endurance performance of a duration of 35 seconds to 2 minute. Short-term endurance is associated with a high activation of the central nervous system, as indicated by EEGs, and high recruitment of fast twitch fibres. The energy for short-term endurance is supplied anaerobically with the ATP-CP system being important for the initial 10 seconds of the exercise [23].

Stretch-shortening cycle: a typical type of movement pattern that occurs in many sport movements including the counter-movement of bob-down in jumping and the wind-up movement in throwing, the stretch-shortening cycle consists of a combination of three contraction types: an eccentric contraction followed by a short isometric contraction, followed by a concentric contraction of the same muscle group. The combined effect of eccentric and concentric contraction exerts greater force or power output than the movements initiated by concentric contraction alone. The enhanced performance is believed to be due to the elastic behaviour of muscles during and immediately after the eccentric contraction [23].

Material and methods

Subjects

The project was approved by the Bioethical Committee at the Regional Medical Chamber (Polish: *Okręgowa Izba Lekarska* in Cracow, Poland, No. 35/KBL/OIL/2011). The study was conducted during the competition period in the training cycle (a week before the European Ju-jitsu Championship). The subjects of the study were twelve female members of the Polish National Team in Sport Ju-jitsu, medal winners in their respective age categories. They have won medals seven times during the European Championships and three times during the World Championships. Their age and sport experience in ju-jitsu were, respectively, 19.5 ± 3.23 and 5.1 ± 3.34 years. They underwent training sessions of 1.5 to 2 hours, 3 to 8 times per week. The average duration of a training session was 7.9 ± 3.59 hours per week. The mean body mass was 58.69 ± 8.38 kg, with the female National Team members participating in four weight categories, i.e.: up to 55 kg (n=6), up to 62 kg (n=3), up to 70 kg (n=2), and over 70 kg (n=1). When fighting, they have also used technical-tactical elements from 9 classification groups: Punches, Kicks, Hand Throws, Hip Throws, Leg Throws, Sacrifice Throws, Holds, Chokeholds and Joint Manipulations.

Anthropometry

Body height measurements were performed using an anthropometer. Body mass was measured using a weight scale (model TBF 300, Tanita Co., Tokyo, Japan). Individual parameters such as age, height, gender, and degree of physical activity (athletic mode) were configurable. The evaluation of body composition was performed under standard conditions according to the guidelines of bioelectric impedance analysis (BIA) [13]. Percentage of fat in total body mass was estimated (PF%). Also calculated were the BMI (body mass index) and body composition (FFMI – fat-free mass index, and FMI – fat mass index) parameters. These parameter take body height into account [14].

Fitness testing

Fitness tests were performed by means of a battery of tests used in karate *(SPFT)* [15, 16] and though the special judo fitness test *(SJFT)* [17, 18]. The testing encompassed the following [12]: *hip turning speed test* (s); *punching speed test* (s); *rapid kicks test* (s); *agility test* (s); *evasive actions test* (s); *push-ups* with one hand clapping per second (maximum repetitions = n); *special judo fitness test* (*SJFT*) comprising the number of throws, heart beats per minute (bpm) and the *SJFT Index*. Exercise reaction was registered using a Polar 810i heart rate monitor (Oy, Finland). In addition, maximal static strength in the dominant hand (HGS) was measured using a handgrip dynamometer (made in the USRR). Results were provided in absolute values (kgf) and relative to body weight.

Statistics

The subjects were divided into two weight categories, lighter (up to 55 kg) and heavier (62 to over 71 kg), and two age categories, senior (older than18) and junior (18 or younger). Sample size distributions were not statistically different (Table 1).

Table. 1. Sample size for age and weight categories of 12 top Polish female ju-jitsu athletes

Groups	Heavier	Lighter	Total
Older	3	3	6
Younger	3	3	6
Total	6	6	12

Once the normality of variable distributions was verified (standardized kurtosis and skewness values should not have exceeded a -2 to 2 range), mean values were calculated, $\bar{x}$ together with standard deviations (SD). Individual characteristics for BMI, FFMI, FMI and PF are shown in the body composition chart [14]. A two-tailed t-test ($p<0.05$) was used to test statistical hypotheses concerning the equality of mean values of measurements and anthropometric/fitness parameters. Cohen's d was calculated [19] and a profile of differences in d between older and younger competitors was created. Effect size (ES) was interpreted [19]: d of 0.2 indicates a small effect, d of 0.5 indicates a medium effect, and d of 0.8 indicates a large effect size. In addition, standard scores (z) for each test result (x_i) were calculated according to the formula: $z = (x_i - \bar{x})/SD$. A sunray plot was then created to demonstrate the results of special ju-jitsu fitness tests on a case-by-case basis. This plot was used to identify the notable case of European and World Championships multimedalist's. The structure of special fitness among female top ju-jitsu competitors was analysed using cluster analysis. All calculations were performed using the STATGRAPHICS.

Results

Body build, body composition and special fitness according to weight and age categories

A very strong correlation between FMI and FFMI ($r=0.98$, $p<0.001$) was observed in the body composition chart (Figure 1).

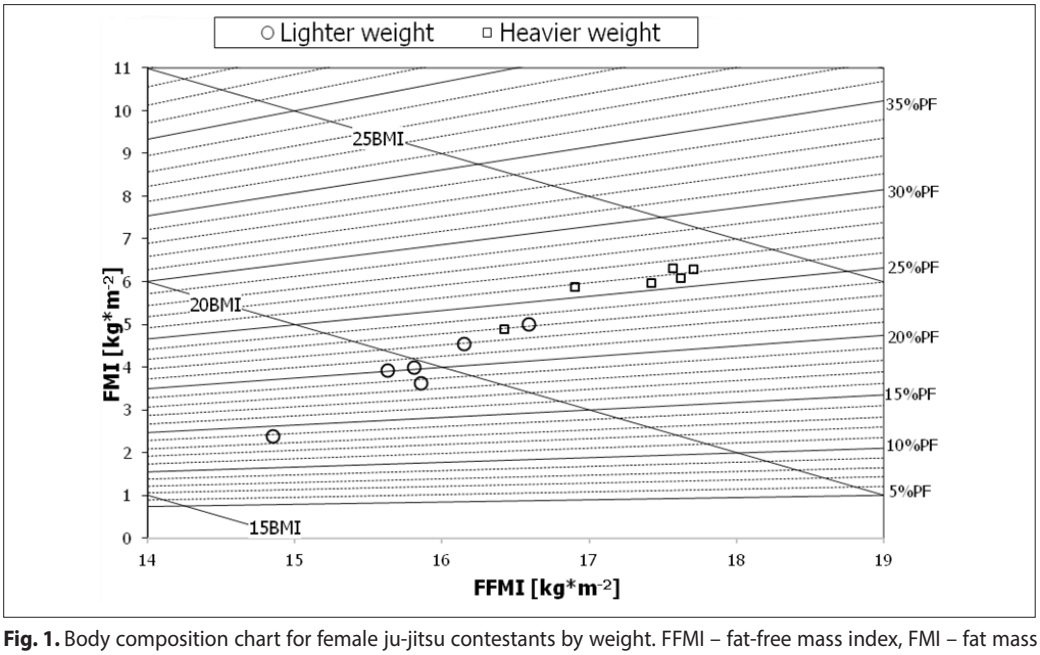

Fig. 1. Body composition chart for female ju-jitsu contestants by weight. FFMI – fat-free mass index, FMI – fat mass index. Oblique lines represent BMI – body mass index and PF – fat percentage in body mass.

The lightest contestant had very low BMI (17.3 $kg\,m^{-2}$), FFMI (14.9 $kg\,m^{-2}$), FMI (2.4 $kg\,m^{-2}$) and PF values (13.8%) (Fig.1.). BMI for all other contestants ranged from 19.5 to 24.0. Body build, body composition and special fitness characteristics of top female contestants in respect to their age, is shown in Table 2.

The mean value for the lighter group was significantly lower than for the heavier group in terms of BMI (19.72 ± 1.47 vs. 23.18 ± 1.02 $kg.m^{-2}$, t=4.72, p<0.001), FFMI (15.82 ± 0.61 vs. 17.27 ± 0.53 $kg.m^{-2}$, t=4.64, p<0.001), FMI (3.91 ± 0.94 vs. 5.90 ± 0.55 $kg.m^{-2}$, t=4.67, p<0.001) and fat percentage in total mass (19.63 ± 3.28 vs. 25.42 ± 1.28, t=4.02, p=0.005). In fitness evaluation, no statistically significant differences were found between the heavier and lighter weight categories in terms of SPFT, HGS

Table 2. Body build, body composition and special fitness characteristics of female contestants

Variable	Whole group (n=12)		Older (n=6)		Younger (n=6)		t-statistic p-value	Cohen's d
	Mean	SD	Mean	SD	Mean	SD		
Anthropometric								
Body mass (kg)	58.69	8.38	57.5	9.52	59.88	7.77	t = -0.47 0.645	-0.28
Height (cm)	165.1	5.1	1.64	0.05	1.66	0.06	t = -0.72 0.489	-0.44
BMI ($kg.m^{-2}$)	21.45	2.17	21.27	2.51	21.63	1.99	t = -0.28 0.785	-0.17
FFMI ($kg.m^{-2}$)	16.54	0.92	16.46	1.06	16.63	0.86	t = -0.31 0.767	-0.19
FMI	4.91	1.25	4.81	1.47	5.002	1.14	t = -0.25 0.805	-0.16
PF	22.53	3.84	22.17	4.71	22.88	3.17	t = -0.31 0.763	-0.19
SPFT								
Hip turning (s)	11.29	3.63	11.52	3.48	11.06	4.09	t = 0.21 0.838	0.13
Punching speed (s)	10.82	2.77	10.83	2.62	10.8	3.17	t = 0.018 0.986	0.07
Flexibility (cm)	166.7	11.6	166.7	15.06	166.7	8.17	t = 0 1.0	0.00
Flexibility index	1.01	0.07	1.015	0.07	1.003	0.06	t = 0.30 0.773	0.19
Rapid kicks (s)	19.28	2.09	18.17	1.70	20.4	1.92	t = -2.13 0.059	-1.35
Agility (s)	17.89	1.84	17.17	0.99	18.62	2.28	t = -1.43 0.184	-0.9
Evasive actions (s)	45.31	3.36	44.32	2.03	46.3	4.29	t = -1.02 0.330	-0.65
Push-ups (reps)*	26.75	5.28	29.67	5.16	23.83	3.76	t = 2.24 0.049	1.42
HGS								
HGS (kgf)	37.75	4.84	38.83	5.67	36.67	4.08	t = 0.76 0.465	0.48
HGS ($kgf.kg^{-1}$)	0.65	0.09	0.68	0.09	0.62	0.08	t = 1.27 0.235	0.80
SJFT								
SJFT- A	6.0	1.21	6.17	0.41	5.83	1.72	t = 0.46 0.655	0.29
SJFT – B	10.2	2.04	11.17	1.94	9.17	1.72	t = 1.89 0.088	1.20
SJFT – C*	9.0	1.04	9.67	0.52	8.33	1.03	t = 2.83 0.018	1.79
Total Throws*	25.2	2.41	27.0	1.55	23.33	1.51	t = 4.16 0.002	2.63
HR after	191.3	27.0	185.3	32.07	197.3	22.15	t = -0.75 0.468	-0.48
HR 1 min after	153.3	25.4	151.3	26.7	155.3	26.34	t = -0.26 0.799	-0.17
HR sum	344.7	50.0	336.7	54.75	352.7	48.43	t = -0.54 0.604	-0.34
Index	13.84	2.60	12.48	2.04	15.21	2.51	t = -2.07 0.066	-1.31
Technical								
Preferred techniques (n)	4.2	1.4	4.67	1.63	3.67	1.03	t = 1.27 0.233	0.80

* denotes a statistically significant difference

and SJFT (p>0.05). The differences between averages in anthropometric measurements and indicators were not statistically significant for the older and younger age categories (p>0.05).

An age-based evaluation showed significant differences between mean values for age categories in the quality of *push-ups* performed, segment *C* of the SJFT and in *total throws*. *The SJFT index* in the older group was better (i.e., lower) than in the younger group. The results of a comparison according to age are presented in Figure 2 and Figure 3, onto which Cohen's d values were drawn that indicate the ES of the age factor. A large ES of contestant age on performance was found for *rapid kicks, agility, push-ups, relative HGS, segments B and C and total throws*, and *the SJFT index*. A medium ES was found for *evasive actions, HGS, segment B of the SJFT, and HR immediately after segment C of the SJFT. The number of preferred technique groups* used in fighting was higher for older than for younger athletes, and the effect size was large.

B. Characteristics of individual fitness profiles

An example of individual characteristics of a senior world champion (Figure 4A and Figure 4B) ranked first in the official ranking of the Ju-jitsu International Federation.

This contestant shows no significant advantage in *hip turning speed* (z = -0.18), nor in *punching rate* (-0.35), although execution time of the latter is shorter (i.e., better) than the group average. The *flexibility index* (range of *mawashi geri*/body height) is a little lower than average (0.30), but high enough for an effective foot kick in the head. Extraordinary differences in comparison to the mean value are present in the following tests: *rapid kicks* (z = -1.34), *agility* (1.28), *evasive actions* (-1.35), relative *HGS* (1.89) and *push-ups* (2.51). In the individual profile No. 2, advantageous differences were observed in the results of the *SJFT*, both for *total throws* (0.68) and the *SJFT index* (-0.41). *The SJFT index* includes an inversely scaled

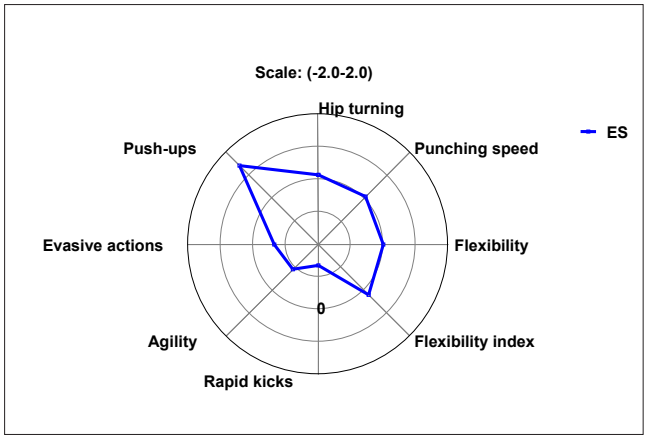

Fig. 2. Effect size of age category on performance in the karate SPFT battery

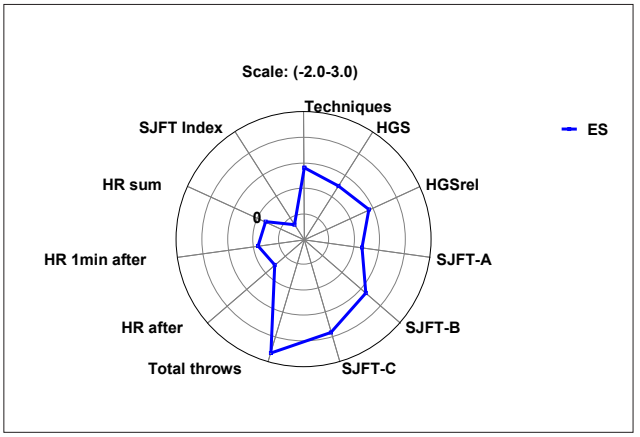

Fig. 3. Effect size of age category on performance in HGS and SJFT

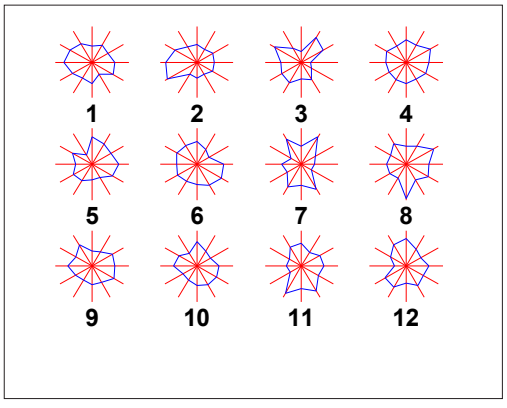

Fig. 4A. Individual profiles in special ju-jitsu fitness tests. Each small polygon is a chart and represents one individual profile. Axes scale is -3 to +3 SD.

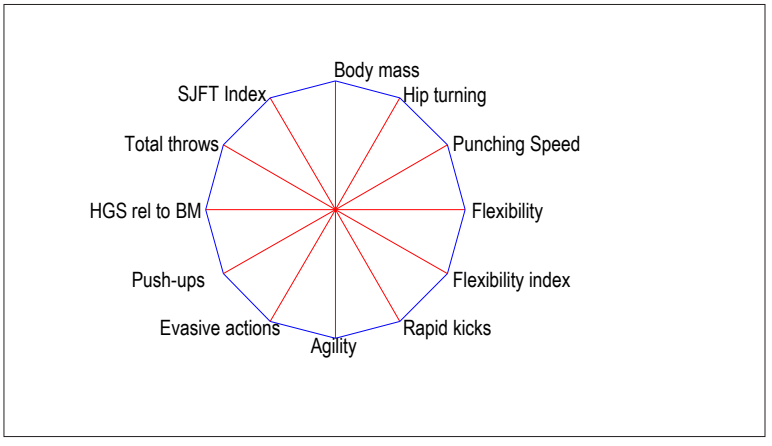

Fig. 4B. Key chart. This plot is used to help interpret Sunray Plots.

variable in respect to *total throws*. A similar profile can be observed for contestant No. 1. What is striking in the graph is how balanced fitness preparation profiles Nos. 4, 6 and 9 are. In contrast, profiles Nos. 3, 7, 8, 10, 11 and 12 show visibly stronger and weaker aspects of individual fitness preparation.

C. Structure of special fitness among female top ju-jitsu competitors

Figure 5 presents a dendrogram of variables grouped in three clusters of special ju-jitsu fitness for top level female sports competitors.

In the first stage, presented on the left side of the dendrogram, the motions used for both attacking and self-defence are logically connected. The first cluster shows the results of *rapid kicks* and actions, connected to which is the *hip turning* speed test. *Hip turning* is needed to perform *Mawashi geri* (a roundhouse kick used in the *rapid kicks* test) and is very useful for absorbing the impact of the fist or foot aimed at the *solar plexus* vulnerability point. Located in the centre of the dendrogram is cluster 2, comprising *punching speed* and *agility.* In fighting, effective use of *punching speed* requires a good estimation of one's distance to a moving opponent. In the *agility* test, spatial orientation and proper change of direction in a zigzag pattern are crucial. Connected to the *punching speed* and *agility* test within this cluster is the *flexibility* test, performed while standing on one leg (similarly as in the *agility* test). On right side of the dendrogram, performance in *push-ups* (a very important skill when fighting in a clinch) and *total throws* are grouped together (cluster 3). Both of the abovementioned tests represent requirements for muscle endurance, and need good neuromuscular coordination because they restrain eccentric and concentric explosive actions, which are dependent on the elasticity of stretched muscles. Since these actions were being repeated in the most time-consuming tests, endurance is also required. In the next stage, the group is connected with *HGS* relative to body mass. This is logical, since no-one is able to throw an opponent without a strong grip. Actions typical for the first phase of fighting are grouped in clusters 1 and 2, whereas actions typical for the second phase of fighting are grouped in cluster 3.

Discussion

Body build and body composition

A comparison between the BMI values of top Polish female ju-jitsu contestants and WHO standards [20] has shown that, with the exception of the lightest one, all contestants had a normal body build. Somatotypes of women from the -55kg, -62 kg, -70 kg and over 70 kg weight categories displayed a very similar

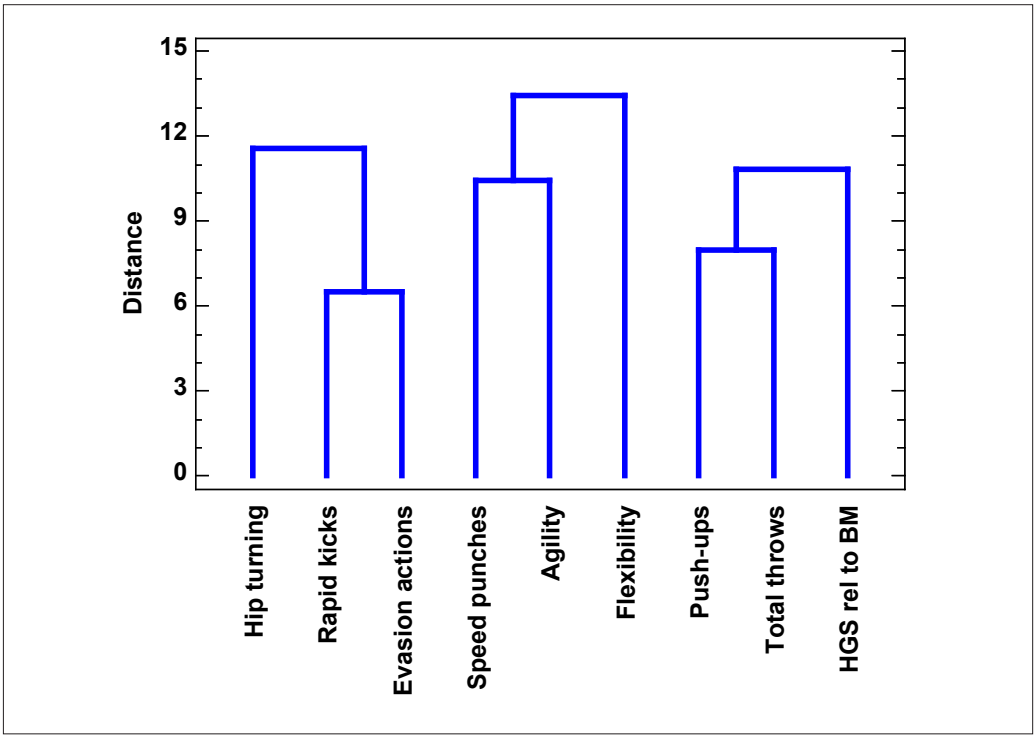

Fig. 5. Dendrogram of variables grouped in three clusters of special ju-jitsu fitness in high sports level female contestants.

mesomorphy share. In the somatochart, they were located along the ectomorphy axis in the endomorphic mesomorph zone [9]. Located within the same area (endomorphic mesomorph) were the somatotypes of female *Kyokushin* karate $\bar{S}$ = 3.86-4.32-2.27 [3] and judo $\bar{S}$ = 4.04-4.89-1.55 athletes [8]. The share of endo-, meso- and ectomorphy components in female ju-jitsu athletes did not depend on their sports level [9]. The authors' previous observations concerned only judoist selected for the national team with a well-established sports level. It was established that female judo athletes display a higher share of mesomorphy than the untrained subjects. Specific training and fighting, where anaerobic power, anaerobic capacity and strength are necessary to overcome external resistance, encourage the development of mesomorphy component, classifying their participant mostly within the endomorphic mesomorph body type [8].

Raschka and Fröhlich [9] concluded that Fat Percentage values of the German female ju-jitsu national team (21.2%) were too high, and postulated a comparative study of other teams. In our current study (BIA) we have observed the mean value of PF to be 22.5%, corresponding to PF levels of the German national team, for which a different method of estimating PF was employed (i.e., measuring skinfolds with a pair of calipers). Polish contestants from the lighter weight category had significantly lower fat percentage in body mass than the heavier category contestants, with a very strong correlation between the FMI and FFMI body composition parameters. Therefore, the higher the proportion of fat in body mass was observed, the higher also was the observed proportion of fat-free mass, meaning that the proportion between FFM and FM was retained. These finding may indicate the effectiveness of a proper selection of national team members in respect to their morphological characteristics, as well as the impact of sports training on the somatic build of female ju-jitsu athletes. Their fatness did not exceed normal levels (cf. Figure 1), since only a PF greater than 30% indicates obesity [7].

Testing fitness in ju-jitsu

As mentioned in the introduction, after a consultation with ju-jitsu coaches it was deemed reasonable to conduct special fitness tests [12]. Motor exercises that were to be performed by trainees in the fitness tests incorporate effort the duration and nature of which is consistent with the rules governing a sport ju-jitsu match (3-minute-long intermittent efforts) [1]. Short bursts of activity and effort nearing several dozen seconds in duration pose strict requirements for anaerobic capacity. Performing these tests, which included technical-tactical elements typical for ju-jitsu, took from a few seconds (*flexibiilty* test) up to as much as 95 seconds for the *SJFT*, in which efforts of 15/30/30 seconds are interspaced with pauses of 10 seconds. The SJFT Index provides date not only on the number of throws performed in the three segments of the test, but also on the HR recovery speed, dependent on a testee's aerobic capacity [18]. The results of comparison between HR immediately after and HR 1 minute after the *SJFT* were better (i.e., HR was lower) for the older group contestants than for younger group contestants. Additionally, the number of throws in the *SJFT* was significantly greater for the older group. Jarmoluk [20] has analysed throws accompanied by turning (such as *Seoi-nage*) and has distinguished muscles that perform dynamic concentric work, dynamic eccentric work, and isometric and static contraction. During the battery of special fitness tests, the older contestants in this study utilized a stretch shortening cycle, a model of which was described by Komi [21], to a probably greater degree, especially for repeated techniques such as: *ippon seoi nage throws, push-ups, hip turning*, jumping on one leg in the *agility* test, and repeated *rapid kicks.*

To our knowledge, not all the results of this study can be compared with the results of other teams. Nevertheless, we may attempt to compare these results with the norms formulated in related disciplines, that is, karate [16] and judo [18]. Such a comparison, though debatable, since the norms have been formulated for males, can still indicate the extent of gender differences within the results of special fitness tests. In this respect, female athletes who participated in the *ju-jitsu* camp would obtain the following scores on a 1 to 5 point scale: *hip turning test* – good (4); *punching speed* – average (3); *flexibility index* – poor (2); *rapid kicks* – average (3); *agility* – very poor (1); *evasive actions* – poor (2); *push-ups* – average (3); *total throws* – poor (2); *HR immediately after* – poor (2); *HR 1 min after* – good (4); *SJFT index* – average (3). Hand grip is required for conveying force when applying throws, joint locks, chokeholds and holds. We found that the relative value of HGS was greater for older contestants than for younger ones. The older group scored significantly better than the younger group in the following tests: *rapid kicks* – good (4) vs. poor (2), *push-ups* – average (3) vs. poor (2), *total throws* – good (4) vs. poor (2), *HR immediately after* – average (3) vs. very poor (1), *SJFT index* – good (4) vs. very poor (1). The evaluation of female contestants against the accepted norms showed gender

differences. What is especially valuable, however, is the confirmation of the quality of performance in tests in respect to contestant age and sports experience.

A direct comparison of ju-jitsu athletes' *SJFT* results is possible only in regard to female judo contestants [22], for whom lower results were observed in *total throws* of older (24 throws vs. 27 throws) as well as younger (22 throws vs. 23 throws). Differences in the *SJFT index* for older contestants were insignificant: 12.6 vs. 12.5, but greater for younger contestants: 14.4 vs.15.2.

The individual profile of the World Champion (No. 2 in Fig. 4A) showed little advantage in exercise tests lasting no longer than 15 seconds (*flexibility index, punching speed* (the rate of hits performed with the upper limbs), and *hip turning*. On the other hand, the World Champion's performance in long-duration tests (*agility test, rapid kicks, evasive actions* and *push-ups*) was far better than the group average. The results of the throwing test (SJFT) were average for the 15-second-long segment *A* (z = -0.10), but an increase in results was observed compared to the group average for the 30-second-long segment *B* (0.37), and most notably in segment *C* (0.91), indicating an uncommon level of special fitness. Consequently, her results in *total throws* indicate a capability to perform strong throws despite growing exhaustion during intermittent effort. Her heart rate immediately after the *SJFT* was high (188 bpm) but dropped to 152 bpm in the first minute of rest, indicating good cardiovascular recovery speed. In addition, the value of the *SJFT index* (HR immediately after the effort + HR after one minute of rest/number of throws) demonstrated the contestant's fitness to be higher (-0.41) in comparison with the group average (the SJFT index scale is inversed, i.e., a lower value signifies a better result).

Structure of Special Fitness among Female Top Ju-jitsu Contestants

HGS relative to body weight, which was used in the datasets of female contestants, substantially enriched their motor fitness structure. *The HGS* parameter was clustered together with *push-ups* and *total throws* in the SJFT, which means we are able to cautiously compare the results of this study with the cluster descriptive analysis from the previous work [12]: "Three groups of tests which characterize special physical fitness of *ju-jitsu* coaches were distinguished the dendrogram. In the first stage, the results of the *hip turning* speed test (movements useful for both attacks and self-defence) and *rapid kicks* were connected. Their common element is undoubtedly the *hip turning* movement, as the *mawashi-geri* kick is impossible to perform without turning one's hips. A cluster containing the *punching rate* test and *total throws* in the *SJFT* was observed. The dendrogram also shows that the next stage at which this combined group was further combined with another cluster was the *push-ups* test. *Punching speed* allows a fighter to open up an opportunity to grip clothes and perform throws. The opponent can also be pushed to prevent him or her from clinching. It is worth noting that this cluster integrates motor effects manifested in actions involving upper limbs (punches, pushing with hands, hand throwing techniques). The cluster on the right of the dendogram is formed by the *agility* test and *evasive actions* test, and is also connected with the *flexibility test*. This cluster contains the methods of moving forwards and backwards employed in fighting. The basis of coordination is formed by spatial orientation and dynamic balance (in both the *flexibility* and *agility* tests, exercises are performed standing on one leg)."

In general, the difference in the structure of special fitness between female representatives and coaches (male) can be explained by gender and age factors. This study was limited by the lack of data in research papers concerning female ju-jitsu athletes, which is why the comparison of somatic build and special fitness of ju-jitsu athletes was performed in respect to female karate and judo athletes. A similar study of male ju-jitsu contestants is needed.

Practical Applications

Conducting an evaluation of female ju-jitsu athletes' fitness preparation showed individual differences, which may prove useful for establishing training goals and motivating trainees. The role of the coach and the contestant is to decide on whether to aim at increasing the (already high) value of a fitness preparation parameter or to maintain it at an optimal level. Moreover, the question remains of how the speed preparation parameters, included in the results of the battery of special fitness tests analysed here, would change if general fitness exercises are used during the general preparation period of the training cycle. The results of the tests performed by the top contestant constitute her individual standards of special fitness, which standards should be aimed at when preparing for an upcoming important competition. Modified training may impact the values of her optimal fitness preparation parameters.

Conclusions

1. Body composition of female ju-jitsu athletes is associated with their weight category, but does not affect performance in special fitness tests.

2. The results of tests that require maintaining dynamic balance when performing *rapid kicks*, local endurance of arm and chest muscles when performing *push-ups*, and special endurance displayed in the *SJFT* (*total throws* and *index*) depend on the age factor.

3. Profile analysis enables a group diagnosis of fitness preparation and demonstrates stronger and weaker points of fitness preparation for individual contestants. That is why it can be used to compare contestants at the time of measurement, as well as in the process of monitoring changes occurring in a training cycle. Normative data for ju-jitsu athletes can be considered.

4. The structure of special fitness among female top ju-jitsu contestants can be used for comparison with male representatives, and for planning and practice.

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Competing interests

The authors declare that they have no competing interests.

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